2013-02

A systematic review of educational interventions to change behaviour of prescribers in hospital settings, with a particular emphasis on new prescribers

Brennan, Nicola

10.1111/j.1365-2125.2012.04397.x
British Journal of Clinical Pharmacology
Wiley

This is a post-print author's draft of an article accepted for publication in the journal British Journal of Clinical Pharmacology 2013. DOI:10.1111/j.1365-2125.2012.04397.x

Title Page

Title: A systematic review of educational interventions to change behaviour of prescribers in hospital settings, with a particular emphasis on new prescribers

Authors:

1. **Submitting and corresponding author**

Dr. Nicola Brennan, PhD – Research Fellow

Institute of Clinical Education,

Peninsula Medical School,

Room C409 Portland Square,

University of Plymouth,

Drake Circus

Plymouth

PL4 8AA.

Tel: 01752 586810,

Fax: 01752 586788

E-mail: nicola.brennan@pms.ac.uk

2. **Other authors**

Dr. Karen Mattick - Associate Director of Undergraduate Medical Studies (Teaching & Learning); Senior Lecturer in Clinical Education

Institute of Clinical Education,

Peninsula Medical School,

St. Lukes Campus,

University of Exeter,

Exeter

EX1 2LU

Tel: 01392 722918

E-mail: karen.mattick@pms.ac.uk

Running Head: Systematic Review of Behaviour Change Interventions

Key words: prescribing, behaviour, new prescribers, hospital, systematic review

Conflict of interest: None

Word Count: 2,778

No. of tables: 6

No. of figures: 1

Structured Summary

Aims

Prescribing is a complex task and a high-risk area of clinical practice. Poor prescribing occurs across staff grades and settings but new prescribers are attributed much of the blame. New prescribers are frequently neither confident nor competent to prescribe and they are likely to have different support and development needs than their more experienced colleagues. Unfortunately, little is known about what interventions are effective in this group. Previous systematic reviews have not distinguished between different grades of staff, have been narrow in scope and are now out of date. Therefore, to inform the design of educational interventions to change behaviour of new prescribers, we conducted a systematic review of existing hospital-based interventions.

Methods

Embase, Medline, SIGLE, Cinahl and PsychINFO were searched for relevant studies published 1994-2010. Studies describing interventions to change the behaviour of new prescribers in hospital settings were included. The bibliographies of included papers were also searched for relevant studies. Interventions and effectiveness were classified using existing frameworks and the quality of studies was assessed using a validated instrument.

Results

Sixty four studies were included in the review. Only 13% interventions specifically targeted new prescribers. Most interventions (72%) were deemed effective in changing behaviour but no particular type or types stood out as most effective.

Conclusion

Very few studies have tailored educational interventions to meet needs of new prescribers, or distinguished between new and experienced prescribers. More research is required if healthcare educators are to support new prescriber and improve this important aspect of early clinical practice.

Introduction

Prescribing is a complex, challenging task and a high-risk area of clinical practice (1). Prescribing errors are common, affecting 7% medication orders, 2% patient days and 50% hospital admissions (2). Studies have identified a range of factors underpinning poor prescribing at individual, environmental and organisational levels (3). These include lack of training, low perceived task importance and lack of awareness of errors, as well as increasingly complex polypharmacy and patient factors, lack of standardization, and particular care environments (4-6).

There is evidence of poor prescribing across different grades of staff and in different settings (5) with new prescribers in particular being attributed a lot of the blame (5, 7). Studies have found that new prescribers are neither confident nor competent when prescribing, both by their own assessment and that of their supervisors (8-10). Many excellent initiatives have focussed on improving prescribing knowledge and technical skills (e.g. Hospital Pharmacy Initiative (11); Medical Schools Councils Safe Prescribing Working Group (12)). However improving prescribing knowledge and technical skills is not enough. Prescribing is a complex mix of knowledge, skills and behaviours and there is no simple relationship between them (13, 14). The skills and experience of new prescribers must develop as they work within an environment where any positive gains may be negated by the numerous complex and overwhelming pressures that may influence prescribing behaviour.

The behaviour change literature is large and growing, supported by research funding to explore the theory and practice of behaviour change, and the development and evaluation

of behaviour change interventions. The challenges inherent in studying behaviour change are widely recognised. Behaviour change not only involves individual capability, opportunity and motivation but the fact that it takes place in a complex healthcare system adds another layer of complexity to the equation (15). There is a plethora of behaviour change theories and frameworks, and behaviour change interventions are equally diverse, leading to challenges of nomenclature (16). A useful way of categorising types of intervention is offered by Bero et al. (17) and this has been adopted in systematic reviews that aimed to determine educational strategies that were effective in changing physician performance and healthcare outcomes (but not necessarily prescribing behaviours) (18, 19). Davis et al. (19) included only randomised controlled trials and found that commonly used educational approaches like didactic presentations had little impact, whereas reminders, patient-mediated interventions, outreach visits, opinion leaders and multifaceted activities were more effective. Bloom (18) reviewed systematic reviews to examine effectiveness of current CME tools and techniques in changing physician clinical practices and improving patient health outcomes and found that interactive techniques such as audit/feedback, academic detailing/outreach and reminders were more effective at changing physician care and patient outcomes than guidelines, opinion leaders, didactic presentations and printed information. Unfortunately, Bloom concluded that "*Even though the cost-effective CME techniques have been proven, use of least-effective ones predominates*".

In order to inform the design of educational interventions that can change the behaviours of new prescribers, we conducted a systematic review of existing interventions. There is no similar study to our knowledge. The most similar review was conducted by Gill et al (20) but it had a narrow methodological scope (only randomised controlled trials and non-equivalent

group designs), did not distinguish between grades of prescriber and is now out of date (only including studies up until 1994). Our study will update this review by identifying educational interventions that aimed to change the behaviour of new prescribers in hospital settings using a deliberately inclusive approach to definitions of educational interventions and study design.

Methods

Search Strategy

The databases used in the systematic review by Gill et al. (20) that are still in use were searched (Embase; Medline; SIGLE), in addition to Cinahl and PsychINFO. The searches were carried out on the 8th and 9th of November 2010 and searched for relevant items published between 1994 and November 2010.

The databases were searched for the following free text keywords in a variety of combinations "prescribing or drug administration or drug prescription or drug utilisation or drug utilization or drug prescription" and "medical education or continuing medical education or nursing education or dental education or clinical education" depending on the database. Subject headings relevant to each database were also used for example MeSH and Emtree. See Table 1 for details of the search used in Medline.

The bibliographies of included papers identified by our search of electronic databases were searched for relevant items by NB & KM. Abstracts were sought for the papers that were considered to be potentially relevant. The inclusion criteria were then applied to these

papers. In addition, the title, abstract or keywords needed to contain the words education to keep in line with our search strategy.

Inclusion Criteria

For the purposes of this review, prescribing was defined as the act of determining what medication a patient should have and the correct dosage and duration of treatment (21).

The following inclusion criteria were adopted:

- Aspect of prescribing - all studies that focused on developing one or more aspect of prescribing as defined above. Studies focusing only on drug administration were not included.

- Study design – all study designs were included.

- Types of settings – all studies that were conducted in hospital settings. This was the setting we were most interested in as the purpose of the review was to inform the design of an educational intervention that develops the behavioural aspects of prescribing in new prescribers, and the vast majority of new prescribers are based in hospital settings. Furthermore we felt that the interventions and reasons underpinning why they might work may be different between hospital and primary care.

- Types of participants – all studies that included doctors, nurses, dentists or other healthcare professionals that prescribe and are in the early stages of their careers i.e. qualified but <2 years post graduation. If the study participants involved all

prescribers in a hospital setting (which would include new prescribers) then it was included.

- Types of intervention – interventions or resources that focus on changing or developing the behavioural aspects of prescribing.
- Outcome measures – all prescribing related outcome measures were accepted.
- Language – studies published in English language.

Data Collection and Analysis

One review author (NB) assessed the potential relevance of all titles and abstracts identified from the electronic searches. As a reliability measure, the first 10% of the titles and abstracts were assessed independently and then compared by the two review authors (NB & KM). If a difference was found the issue was discussed. The remaining title and abstracts (90%) were assessed independently by NB. If NB had any doubts about particular studies while assessing them they were resolved by discussion with KM. A categorisation system was developed to categorise excluded papers (Figure 1).

Data Extraction and Quality Appraisal

The papers of all eligible studies were obtained and read in full and data were extracted by each review author. Data were extracted independently using a standardised review form. Interventions were categorised using the same classification as the Gill(20) study which was based on Bero et al (see Table 2). Where possible the pre and post test scores were extracted but some studies failed to report these and in these cases the numerical or percentage change were reported instead. The effectiveness of interventions were

categorised using a modified version of the classification system used in the Gill (20) study (see Table 3). It was not possible to use an identical framework to Gill et al. because this relied on the statistical significance of change in the outcomes measured and very few of our included studies conducted this type of analysis. Our modified approach is described in Table 3 and the categorisation was applied independently by both NB and KM. >95% agreement was reached between KM and NB using this method. The few differences that were found were discussed and agreement was reached.

The quality of studies were appraised using the medical education research study quality instrument (MERSQI) (Table 4) (22). This tool was the most appropriate for this review because the majority of interventions included in the study had an educational, conference or training element to the intervention. Furthermore the majority of studies were observational or experimental and the MERSQI was designed for these study designs. The six items on the MERSQI scale (study design, sampling, type of data, validity of evaluation instrument, data analysis, and outcomes) were scored on a scale of 1 to 3 and summed to determine a total MERSQI score. The maximum score for each domain was 3, producing a maximum possible MERSQI score of 18 and potential range of 5 to 18. The total MERSQI score was calculated as the percentage of total achievable points (accounting for "non applicable" responses) and then adjusted to a standard denominator of 18 to allow for comparison of scores across studies (22). Both reviewers independently scored the papers using the MERSQI tool and consistent scores were found.

Results

Literature Identified

The search identified 5,966 potentially relevant articles and after the exclusions were applied 53 articles satisfied the inclusion criteria (Figure 1). Checking the references of the 53 included items identified 11 more relevant studies. The 64 studies included in the analysis are listed in Table 5.

Description of Studies

Only 13% of interventions specifically focussed on new prescribers. The majority of studies were conducted in the USA and Canada (39%) and Europe (33%) (Table 5). In terms of clinical area, 38% were conducted in internal medicine, 27% were carried out in all clinical areas and 13% were carried out in paediatrics. A variety of drug types were involved, with the largest group being antibiotics (32%).

The majority of studies were single group pre test and post test (72% n=46), with the remainder being either non-randomized 2 group (11%, n=7), randomised control trials (9%, n=6) and single group cross-sectional or single group post test only (8%, n=5). Nearly all of the interventions were multifaceted (89%) using a variety of combinations of interventions. Within the 64 eligible studies there were 157 separate interventions (Table 2) with educational materials (28%), conferences and training (23%) and audit and feedback (18%) being the most popular. A variety of outcome measures were used in the studies but the most common were the rates of prescribing, rates of appropriate/inappropriate prescribing, prescribing errors, adherence to dosage guidelines and cost savings. The majority of interventions were classified as being effective (72%): 45% received a + and 27% received a

++. Of the 17 (27%) most successful strategies (classified as ++) 6 provided specific feedback to prescribers (e.g. audit and feedback (23-28) and 7 required active engagement with the process (e.g. reminders (26, 29-34). However, 7 of the 8 studies classified as ineffective also contained these intervention types (35-41).

Quality of Studies

Total MERSQI scores among the 64 studies ranged from 6 to 18 with a mean (SD) of 13.3 (1.7) (Table 6). Mean domain scores were highest for type of data (3.0), data analysis (2.8) and outcomes (2.0). Only 19.4% of studies were multi-institutional. All of the studies measured a behavioural outcome, two of which included patient outcomes.

Discussion

The aim of this systematic review was to identify educational interventions that aimed to change behaviour of new prescribers. A previous systematic review explored this topic but had a narrow methodological scope, did not focus on new prescribers and is now out of date. We focussed on the hospital setting since this is where the majority of new prescribers are based and since we felt the issues facing prescribers in primary and secondary care were probably different, and might require different strategies for behaviour change.

We identified a reasonable size literature relevant to our aim. However, only 19% of studies distinguished between different grades of prescriber and even fewer (13%) focussed on new prescribers. A systematic review investigating the effectiveness of education interventions

whose target population was medical students and junior doctors similarly found a very small number of studies on junior doctors (3). The limited focus on new prescribers probably reflects the predominant use of before and after studies where the outcome measure was hospital pharmacy data or patient notes. It is not possible and / or labour intensive to differentiate between grades of staff in these data sources. New prescribers are a very distinct group with different educational needs than more experienced prescribers and we think that different behaviour change strategies will be effective thus it is important that educational interventions are designed specifically to target this group.

The educational interventions reported in the included studies were varied and were mainly used in various combinations. The findings show that 72% of interventions were deemed effective in changing prescribing behaviour in the intended direction. However, similar to the Gill et al. study (20), no clear differences in the effectiveness of particular types or combinations of interventions could be deciphered. This contrasts with the Davis (19), Bloom (18) and Grindod (42) studies which found particular types of interventions like audit and feedback, reminders, outreach were consistently effective (although none of these studies contained information on the sustainability of effect of these interventions). The inconsistencies in findings is probably related to the fact that prescribing behaviour is complex and therefore, by definition, unpredictable. Interventions to improve professional performance are complex and "*any cogent interpretation of the results of these studies requires a disentangling of the variation in the characteristics of the targeted professionals, the targeted behaviours and the study designs*"(43). Our data suggest that a successful strategy in one setting may not be successful in another setting.

Only 11% of our studies reported single interventions compared to 67% in the Gill et al. study. This shows a marked temporal shift from single to multifaceted interventions. While our study did not provide reliable evidence that multifaceted interventions were more effective, other studies have indicated that this is the case (42, 44). Furthermore there were only 6 RCTs included in our study compared with 64 in the Gill et al. review and we believe this finding represents a real decrease in the number of RCTs performed. This shift may reflect an increasing awareness that RCTs are limited in their ability to help us understand a complex behaviour like prescribing, although there are a number of other possible explanations.

Our research aimed to identify educational interventions that were designed to effect behavioural change in new prescribers. Despite including all types of study design, there was very little that contributed to the picture of why or how particular behaviour change strategies produced their effect and this is an important next step. Mixed methods study designs will be important in this respect and different types of systematic review such as a realist review may also be helpful (45). Traditional methods of review focus on measuring and reporting the effectiveness of interventions but provide limited information as to why the intervention worked or did not work when applied in different contexts or circumstances, deployed by different stakeholders, or used for different purposes (45). A realist review is designed to work with complex social interventions or programmes and provides an explanatory analysis aimed at discerning what works, for whom, in what circumstances, in what respects.

The strengths of the research approach were the considerable efforts that went into locating relevant studies. Publication bias is the most important source of bias in systematic reviews (46). This is likely the case in this study, given that the majority of the interventions were effective. One wonders whether the authors would have sought to publish them if they had not had the desired effect.

A limitation of this review is the subjective nature of the direction and magnitude of the effect scores. While the MERSQI scale was helpful for assessing the quality of studies, like most quality assessment tools it did have some limitations. The perfect score of 3.0 for type of data was because the quality scale is not applicable to prescribing interventions included in this review, so by nature of the inclusion criteria, all the studies got a perfect score on this component. Other limitations were the reliance on pre-post test designs which can be confounded by improvement of prescriber with time and clinical experience, another is the possible absence of blinding in studies with risk of observer bias, and finally selective outcome reporting with a tendency to report favourable outcome measures in the manuscript.

In terms of future research, behaviour change strategies targeting specific grades of prescriber are urgently needed if we are to reduce the morbidity and mortality resulting from prescribing errors. Quantitative studies (such as a before and after study with a control hospital, or an RCT) could be enhanced by the inclusion of a process evaluation to unpick the possible reasons underpinning prescribing behaviours (47) as none of the studies in this review included this element.

Table 1: Medline Search

1. "Drug Utilization Review"/ or Drug Prescriptions/ or Drug Utilization/ or drug utilisation.mp.

2. prescription drugs.mp. or Drug Prescriptions/ or Prescription Drugs/

3. medication errors.mp. or Medication Errors/

4. prescribing.tw.

5. (drug$ adj4 administ$).tw.

6. (drug$ adj4 prescri$).tw.

7. (drug$ adj4 utilisation).tw.

8. (drug$ adj4 utilization).tw.

9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8

10. medical education.mp. or Education, Medical/

11. continuing medical education.mp. or Education, Medical, Continuing/

12. nursing education.mp. or Education, Nursing/

13. dental education.mp. or Education, Dental/

14. Education, Professional/ or Education, Medical/

15. Education, Medical/ or clinical education.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]

16. Education, Medical/ or Education, Medical, Graduate/ or doctor training/ or interprofessional education.mp.

17. 10 or 11 or 12 or 13 or 14 or 15 or 16

18. 9 and 17

Table 2: Classification and Types of Intervention (20)

Type of Intervention	No. of Interventions	%
Educational materials: Distribution of published or printed recommendations for clinical care, including clinical practice guidelines, audiovisual materials and electronic publications	44	28
Conferences & Training: Participation of healthcare providers in conferences, lectures, workshops or traineeships outside their practice settings. Practice settings are defined as on the ward or in their office. But could be taking place in a room on the hospital site.	36	23
Audit & Feedback: Any summary of clinical performance of health care over a specified period, with or without recommendations for clinical action. The information can have been obtained from medical records, computerised databases or patients or by observation including a knowledge test.	27	17
Outreach Visits: Use of a trained person who meets with providers in their practice settings to provide information. The information given may include feedback on the providers performance. Practice settings are defined as on the ward or in their office. But could be taking place in a room on the hospital site.	15	10
Reminders: Any intervention (manual or computerised) that prompts the healthcare provider to perform a clinical action. Examples include concurrent or inter-visit reminders to professionals about desired actions such as screening or other preventative services, enhanced laboratory reports or administrative support (e.g. follow-up appointment systems or stickers on charts, order forms or physician order entry systems).	24	15
Marketing: Use of personal interviewing, group discussion (focus groups) or a survey of targeted providers to identify barriers to change and the subsequent design of an intervention and refinement.	9	6
Patient-mediated interventions: Any intervention aimed at changing the performance of health care providers for which information was sought from or given directly to patients by others (e.g. direct mailings to patients, patient counselling delivered by others, or clinical information collected directly from patients and given to the provider)	1	1
Local opinion leader: Use of providers explicitly nominated by their colleagues to be educationally influential	1	1
Total	157	100

Table 3: Classification of Effectiveness of Intervention

Effectiveness of Intervention	**Symbol**
Intervention was ineffective or demonstrated no intended effect	o
Intervention resulted in a change in the opposite direction	-
Intervention resulted in a positive change of 20-50% from baseline, in the majority of outcomes measured at the first post measure. If one outcome was classified as a + and one was a ++, the overall classification was a +.	+
Intervention resulted in a positive change of >50% from baseline in the majority of outcomes measured at the first post measure	++
Intervention resulted in a variable change of outcome measures and included both a positive (+ or ++) and a negative (-) or ineffective outcome (0).	v

Table 4: MERSQI Scale

Domain		MERSQI Item	Item Score	Please put x in relevant box
Study Design	**1.**	**Study design**		
		Single group cross-sectional or single group post test only	1	
		Single group pre test and post test	1.5	
		Nonrandomized, 2 group	2	
		Randomized controlled trial	3	
Sampling	**2.**	**No. of institutions studied**		
		1	0.5	
		2	1	
		>2	1.5	
	3.	**Response rate, %**		
		Not applicable		
		< 50 or not reported	0.5	
		50-74	1	
		>- 75	1.5	
Type of data	**4.**	**Type of data**		
		Assessment by study participant	1	
		Objective measurement	3	
Validity of evaluation instrument	**5.**	**Internal structure**		
		Not applicable		
		Not reported	0	
		Reported	1	
	6.	**Content**		
		Not applicable		
		Not reported	0	
		Reported	1	

	7.	**Relationships to other variables**		
		Not applicable		
		Not reported	0	
		Reported	1	
Data analysis	**8.**	**Appropriateness of analysis**		
		Data analysis inappropriate for study design or type of data	0	
		Data analysis appropriate for study design and type of data	1	
	9.	**Complexity of analysis**		
		Descriptive analysis only	1	
		Beyond descriptive analysis	2	
Outcomes	**10.**	**Outcomes**		
		Satisfaction, attitudes, perceptions, opinions, general facts	1	
		Knowledge, skills	1.5	
		Behaviours	2	
		Patient/health care outcome	3	
Total Score				

This is a post-print author's draft of an article accepted for publication in the journal British Journal of Clinical Pharmacology 2013. DOI:10.1111/j.1365-2125.2012.04397.x

Table 5: Studies of effects of interventions on prescribing behaviour of new prescribers

		Context				Methods			Results		Study Quality
	Study	**Country of study**	**Clinical area**	**Type of new prescriber**	**Drug prescribed**	**Study design** **A = Single group cross-sectional or single group post test only** **B= Single group pre test & post test** **C= Non-randomized, 2 group** **D=Randomized control trials**	**Type of intervention(s)**	**Outcome measures**	**Pre & post measures**	**Effectiveness of Intervention** **(o) = ineffective** **(+) = moderately effective** **(++) = highly effective**	**MERSQI Score out of 18**
1.	Akter et al (2009)(48)	Bangladesh	Paediatrics	All prescribing doctors	Antibiotics	C	Conferences & training	Inappropriate antimicrobial use (pneumonia & diarrhoea)	83.1 to 66.7%, 86.8% to 28.0 %	+	15
2.	Allenet et al (2004)(49)	France	Medicine	All prescribers	Not specified	A	Outreach visits, audit & feedback	Rate of acceptance of pharmacy residents recommendations	47% & 80% acceptance	No baseline data – not possible to calculate	10
3.	Angalakuditi et al (2005)(50)	Australia	Paediatrics	All prescribing doctors	Antibiotics	C	Educational materials, audit & feedback	1. Appropriate antibiotic choice 2. Dosage	1. 48% to 84.7% 2. 0 to 58.2%	+	15
4.	Apisarnthanarak et al (2006)(51)	Thailand	All clinical areas	All prescribers	Antibiotics	B	Educational materials, conferences & training, reminders	1. Rate of prescription 2. Inappropriate use 3. Drug resistant infection 4. Cost	1. 64 to 40% 2. 42 to 20% 3. 48 to 33.5%	+	13

								savings	4. $84,450 to $52,219		
5.	Apisarnthanarak et al (2007)(35)	Thailand	Medicine & Surgery	All prescribers	Antibiotics	B	Educational materials, reminders	Rate of inappropriate antibiotic use	20 to 23%	0	13
6.	Apisarnthanarak et al (2010)(52)	Thailand	All clinical areas	Doctors, residents, interns and medical students	Antifungals	B	Educational materials, reminders	1.Rate of prescription 2. Rate of inappropriate drug use, 3. Cost savings	1. 194 to 80 2. 71 to 24% 3. $31,615 (baseline data absent)	++	13
7.	Bantar et al (2003)(53)	Argentina	All clinical areas	All prescribers	Antibiotics	B	Audit and feedback, reminders, marketing	1. Antibiotic use 2. Cost	1. 431 to 276 2. $261,955 to $57,245	+	13
8.	Belgamwar (2005)(29)	UK	Medicine	All prescribers	Parenteral Thiamine	B	Educational materials	Average number of monthly prescriptions	1. 79 to 208	++	14
9.	Bell (2002)(54)	USA	All clinical areas	All prescribers	Antibiotics	B	Educational materials, audit & feedback	1. Antibiotic use 2. Antibiotic claims 3. Cost	Not possible to report due to large number of data from different organisations	+	13
10.	Bergqvist (2009)(55)	Sweden	Medicine	All prescribing nurses	All drugs	B	Conferences & training	1. Drug-related readmissions 2. Rate of inappropriate drug use	1. 36.1 to 37.6% 2. 17.6 to 17.2	O	14
11.	Buckmaster et al (2006)(56)	Australia	Emergency Medicine	Junior doctors	Heparin & enoxaparin	C	Educational materials, outreach visits, reminders, marketing	Inappropriate drug use	90% decrease	++	15
12.	Burmester et al (2008)(57)	USA	Paediatrics	All prescribers	Not specified	B	Outreach visits, audit &	1. Prescribing errors 2.	1. 16.8 to 8.4%	+	13

							feedback, reminders	Incomplete prescriptions 3. Adverse drug events	2. 15.3 to 3.6% 3. 1.3 to 1.1%		
13.	Buyle et al (2010)(58)	Belgium	Medicine & Surgery	All prescribing doctors	Antibiotics	B	Educational materials, conferences & training, reminders	1. Ratio of consumption 2. Number of days beyond advised IV 3. Cost	1. 44.5 to 41.2% 2. 4.1 to 3.5 3. €188 to €103	v	13
14.	Campino et al (2009)(30)	Spain	Pediatrics	All prescribers	All drugs not related to enteral and parenteral nutrition and blood products	B	Conferences & training	1. Medication errors 2. % of drug prescriptions with one or more incident 3. Ability to identify prescribing physicians	1. 20.7 to 3% 2. 19.2 to 2.9% 3. 1.3 to 78.2%	++	13
15.	Carson et al (2009)(59)	Ireland	All clinical areas	All prescribing doctors and nurses	Opiods	B	Educational materials, conferences & training, audit & feedback, outreach visits	1. Rate of drug errors	1. 54 to 17	++	12
16.	Caswell et al (2006)(60)	UK	Medicine	Junior doctors & nurses	Hypnotics	B	Conferences & training, educational materials	1. Inpatient use of hypnotics 2. Discharge use of hypnotics	1. 48 to 26% 2. 20 to 10%	+	13
17.	Chaturvedi et al (2008)(23)	India	Psychiatry	Resident doctors	Not specified	B	Audit & feedback	Prescriptions meeting required standards	8 to 40%	++	12
18.	Cohn et al (2006)(61)	USA	Medicine	All prescribers	VTE Prohpylaxis	B	Conferences & training, audit & feedback, reminders	1. Rate of prophylaxis 2. Rate of appropriate prophylaxis	1. 43 to 86% 2. 68 to 85%	+	13
19.	Corfield et al (2006)(24)	UK	Surgery	Nurses & junior doctors	Cardiac drugs	B	Educational materials, audit & feedback	1. Proportion of patients with cardiac drugs	1. 42 to 20%	++	13

								omitted 2. Proportion of patients with a drug omitted with the reason stated as 'nil by mouth'	2. 13.3 to 0%		
20.	Cote et al (2008)(25)	USA	Medicine	All prescribing doctors	GI Prophylaxis	A	Outreach visits, reminders	Use of gastroprotection	26 to 55%	++	11
21.	De Melo et al (2008)(31)	Brazil	Medicine	All prescribers	Antibiotics	B	Outreach visits, marketing	1. Use of inappropriate antibiotics 2. Cost savings	1. 69.2%, 56.3% 39.0% reduction 2. 58.6%	++	13
22.	De Miguel et al (2000)(62)	Spain	All clinical areas	All prescribers	Albumin	B	Educational materials, conferences & training	1. Rate of appropriate prescribing 2. Cost	1. 76 to 39% 2. $108,750 to $102,950	v	13
23.	Donovan et al (2007)(63)	USA	Medicine	Cardiologists	Eptifibatide Renal dosing	C	Conferences & training	1. Adherence rate to dosing recommendations	1. 37 to 69%	+	15
24.	Foulks et al (1997)(36)	USA	Surgery	All prescribing doctors & nurses	Parenteral nutrition	B	Educational materials, reminders	1. Overfeeding of kilocalories 2. Cost of delivery of a patient-day of TPN	1. 125 to 110% & 120 to 105% 2. 8% decrease	0	14
25.	Frush e al (2006)(64)	USA	Paediatrics	Doctors, nurses & paramedics	Not specified	C	Conferences & training	1. Dosing deviation summary 2. Dosing time summary	1. 34.4 to 12.6% 2. 29 to 16	+	17
26.	Garbutt et al (2008)(65)	USA	Medicine & surgery	Medical house staff & surgeons	Not specified	B	Conferences & training, audit reminders	Prescribing errors for 1. surgical and 2. house staff	1. 1.08 to 0.85 2. 0.76 to 0.98	v	13
27.	Gommans et al (2008)(66)	New Zealand	All clinical areas	Doctors & nurses	Not specified	B	Educational materials, conferences & training, audit &	Documentation of medical charts including 1.	1. 14 to 97%	++	12

							feedback, reminders	Legibility, 2. Patient identification, 3. Documentation of date, 4. Drug dose 5. Use of medication alerts 6. Prevalence of verbal orders	2. 58 to 81% 3. 11% to 98% 4. 11% to 99% 5. 53 to 98% 6. 15 to <1%		
28.	Gordon et al (2000)(37)	USA	All clinical areas	All prescribers	Meperidine	B	Educational materials, conferences, audit & feedback, reminders	Use of meperidine	1. 12 to 11%	0	12
29.	Gyssens et al (1997)(67)	Netherlands	Medicine	Medical students, residents, junior & senior staff members	Antibiotics	B	Conferences & training, educational materials, reminders, audit & feedback	1. Defined daily doses of antimicrobial use 2. Compliance with order form	1. 31 to 21% 2. 40 to 53%	+	13
30.	Kaye et al (2005)(38)	Australia	Emergency medicine	All prescribing doctors	Analgesics	C	Educational materials, audit & feedback, marketing	Dosage units of parenteral analgesics	62 vs 56%	0	14
31.	Khali et al (2010)(68)	Iran	Medicine	All prescribing doctors	Acid suppressive therapy	B	Educational materials, conferences & training, outreach visits	Appropriate drug use	1. 81 to 48%	+	12
32.	Kozer et al (2006)(39)	Canada	Paediatrics	Interns & resident doctors	Not specified	A	Conferences & training, audit & feedback	Rate of prescribing errors	12.4% vs 12.7%	0	11
33.	Le Claire et al (2006)(40)	USA	Medicine	Medical house staff officers, physicians & pharmacists	Antibiotics	B	Educational materials, reminders	Appropriate drug use	45 to 51%	0	13
34.	Leonard et al (2006)(69)	USA	Paediatrics	All prescribers	All drugs	B	Educational materials, audit & feedback	1. Absolute risk reduction, 2. Potential adverse drug event	1. 38 to 49% 2. 78 to 35.3%	+	13

35.	Lewis et al (2010)(26)	UK	All clinical areas	All prescribing doctors	Insulin	B	Conferences & training, audit & feedback	Number of incorrect abbreviations	37.5 to 15.5%	++	13
36.	Lipsky et al (1999)(70)	USA	All clinical areas	All prescribers	Antibiotics	B	Educational materials, outreach visits, marketing	Rate of inappropriate prescribing	70 to 40%	+	13
37.	Lutters et al (2004)(71)	Switzerland	Medicine	All prescribers	Antibiotics	B	Educational materials, conferences & training sessions, outreach visits, audit & feedback	1. Mean number of prescribed drugs 2. Proportion of patients exposed to antibiotic agents 3. Number of antibiotics administered. 4. Cost of antibiotic use	1. 5.9 to 7.6% 2. 15% reduction 3. 26% reduction 4. 54% reduction	v	13
38.	McQuillan et al (1996)(72)	UK	Medicine	All prescribing doctors & nurses	Analgesics	B	Educational materials, conferences & training, local opinion leader	1. Rate of appropriate prescribing for a variety of analgesic types 2. pain scores	1. 6.2 to 13.7%, 5.6 to 14.4% , 7.3 to 0.7%, 6 to 6% 2. 15 too 22%	v	15
39.	Metlay et al (2007)(41)	USA	Emergency medicine	All prescribers	Antibiotics	D	Conferences & training, educational materials, patient-mediated interventions, audit & feedback	Inappropriate antibiotic use for 1. Upper respiratory tract infection 2. Acute bronchitis	1. 9.5% decrease 2. 5% decrease	0	18
40.	O' Connor et al (2005)(27)	USA	Medicine & surgery	Residents, nurse practitioners & physician assistants	Opiods	B	Educational materials, reminders	Doses of meperidine	37.5 to 0.22	++	12
41.	Peeters et al (2009)(73)	USA	Medicine	All residents	Not specified	B	Conferences & training, marketing	Frequency of prescribing error	2.25 to 1.51	+	12

42.	Perez et al (2003)(74)	Columbia	Medicine, Surgery & Paediatrics	All prescribers	Antibiotics	B	Educational materials, conferences & training, reminders	Incorrect prescriptions	47, 7.3 & 20% reduction	+	13
43.	Record et al (1995)(75)	USA	All clinical areas	House staff doctors	Antibiotics	A	Educational materials, reminders	Compliance with criteria	89%	No baseline data – not possible to calculate	10
44.	Regal et al (2010)(32)	USA	Medicine	Attending doctors, senior medical officers & interns	Acid suppressive medications	B	Conferences & training, outreach visits	Inappropriate prescribing	59 to 19%	++	13
45.	Richards et al (2003)(76)	Australia	All clinical areas	All prescribers	Antibiotics	B	Conference & training, Reminders	1. Rate of drug use 2. Concordance with guidelines	1. 38.3 to 15.9 2. 25 to 51%	++	13
46.	Riggio et al (2009)(33)	USA	Medicine	All prescribing doctors & nurses	Heart failure drugs	B	Conferences & training, reminders	Compliance	37 to 93%	++	13
47.	Roberts et al (2006)(77)	Australia	Medicine & Surgery	All prescribers	Warfarin	A	Educational materials, audit & feedback	Uptake of DVT prophylaxis by 1. medical patients 2. Surgical patients	1. 52.8 to 67% 2. 86.1 to 84.1 %	v	13
48.	Roth et al (2001)(78)	USA	All clinical areas	All prescribing doctors, residents & physician extenders	Anticoagulants, histamine type 2 blockers & non steroidal anti-inflammatory drugs	B	Educational materials, audit & feedback, reminders	Total prescriptions	32%, 50%, 28% decrease	+	13
49.	Ruttiman et al (2004)(79)	Switzerland	Medicine	All prescribers	Antibiotics	B	Educational materials, conferences and training sessions, outreach visits, audit & feedback	1. Antibiotic consumption 2. Cost of antibiotics	1. 36% decrease 2. 53% decrease	+	13
50.	Sarasin et al (1999)(80)	Switzerland	Medicine	All prescribing doctors	Beta blockers	B	Educational materials, conferences &	Prescription of beta blockers at	1. 38 to 63%	+	13

							training, reminders	discharge			
51.	Seto et al (1996) (81)	Hong Kong	All clinical areas	All prescribers	Antibiotics	B	Educational materials, conferences & training sessions, audit & feedback, marketing	1. Admissions prescribed IV sultamicillin or coamoxiclav 2. Cost	1. 38 & 75% reduction 2. 43% decrease	+	13
52.	Shaw et al (2003)(82)	Australia	All clinical areas	Junior doctors	Drugs of addiction	C	Educational materials, marketing	1. Rate of errors 2. Confidence of junior doctors in writing prescriptions	1. 41 to 24% 2. 3.25 to 4.14	+	15
53.	Shah et al(83) (2003)	USA	Paediatrics	Residents	Paediatric drugs	D	Educational materials, conferences & training,	Deviation from recommended dose range	25.4% decrease	+	15
54.	Simpson et al (2004)(34)	Scotland	Paediatrics	All prescribers	Paediatric drugs	B	Educational materials, outreach visits, audit and feedback	Monthly medication errors	24.1 to 5.1	++	13
55.	Solomon et al (2001)(84)	USA	Medicine	Intern & resident doctors	Antibiotics	D	Educational materials, audit & feedback	Unnecessary drug use(days)	37% decrease	+	15
56.	St. Pierre et al (2005)(28)	USA	Medicine	All prescribing doctors, nurse pharmacists & therapists	Delerogenic drugs	B	Educational materials, conferences & training	Frequency of medication use	57% reduction	++	12
57.	Sterne et al (1996)(85)	USA	All clinical areas	All prescribers	Ranitidine	B	Educational materials, outreach visits, reminders	1. Appropriate drug use 2. Appropriate dosage form 3. Cost savings	1. 74 to 96% 2. 87 to 94% 3. $1,080 to $180	+	13
58.	Thamlikitkul et al (1998)(86)	Thailand	All clinical areas	Student doctors, residents & doctors	Antibiotics	B	Educational materials, conferences & training, audit & feedback	1. Antibiotic use 2. Cost of antibiotics	1. 20% decrease 2. 20% decrease	+	13
59.	Thompson et al (2008)(87)	UK	Psychiatry	All prescribers	Antipsychotics	D	Educational materials,	Polypharmacy	Ranging from a reduction of 26% to	v	17

							outreach visits, reminders	prescribing rates	an increase of 7%		
60.	Thompson et al (2010)(88)	UK	Psychiatry	All prescribing doctors & nurses	Antipsychotic drugs	D	Educational materials	Proportion of antipsychotic polypharmacy prescribing	Ranging from a reduction of 26% to an increase of 7%	v	17
61.	Ungavari et al (1997)(89)	Hong Kong	Psychiatry	All prescribers	Psychotropic drugs	B	Educational materials, conferences & training, audit & feedback	Drug use	54.3 to 34.2	+	13
62.	Van Hees et al (2008)(90)	Netherlands	Medicine & Surgery	All prescribers	Antibiotics	B	Conferences & training, marketing	1. Quantity of prescriptions 2. Quality of prescriptions	1. 81 to 32 2. 53.6 to 75.7	+	13
63.	Webbe et al (2007)(91)	UK	Emergency medicine & medicine	Junior doctors	Not specified	D	Educational materials, conferences & training, outreach visits, audit & feedback	1. Rate of prescribing errors 2. Performance on prescribing assessment	1. 37.5% reduction 2. 55 to 61	+	15
64.	Zamin et al (1997)(92)	Canada	Medicine	Residents, interns, medical students & pharmacists	Antibiotics	B	Educational materials, conferences & training sessions	Inappropriate prescribing	41 to 26%	+	12

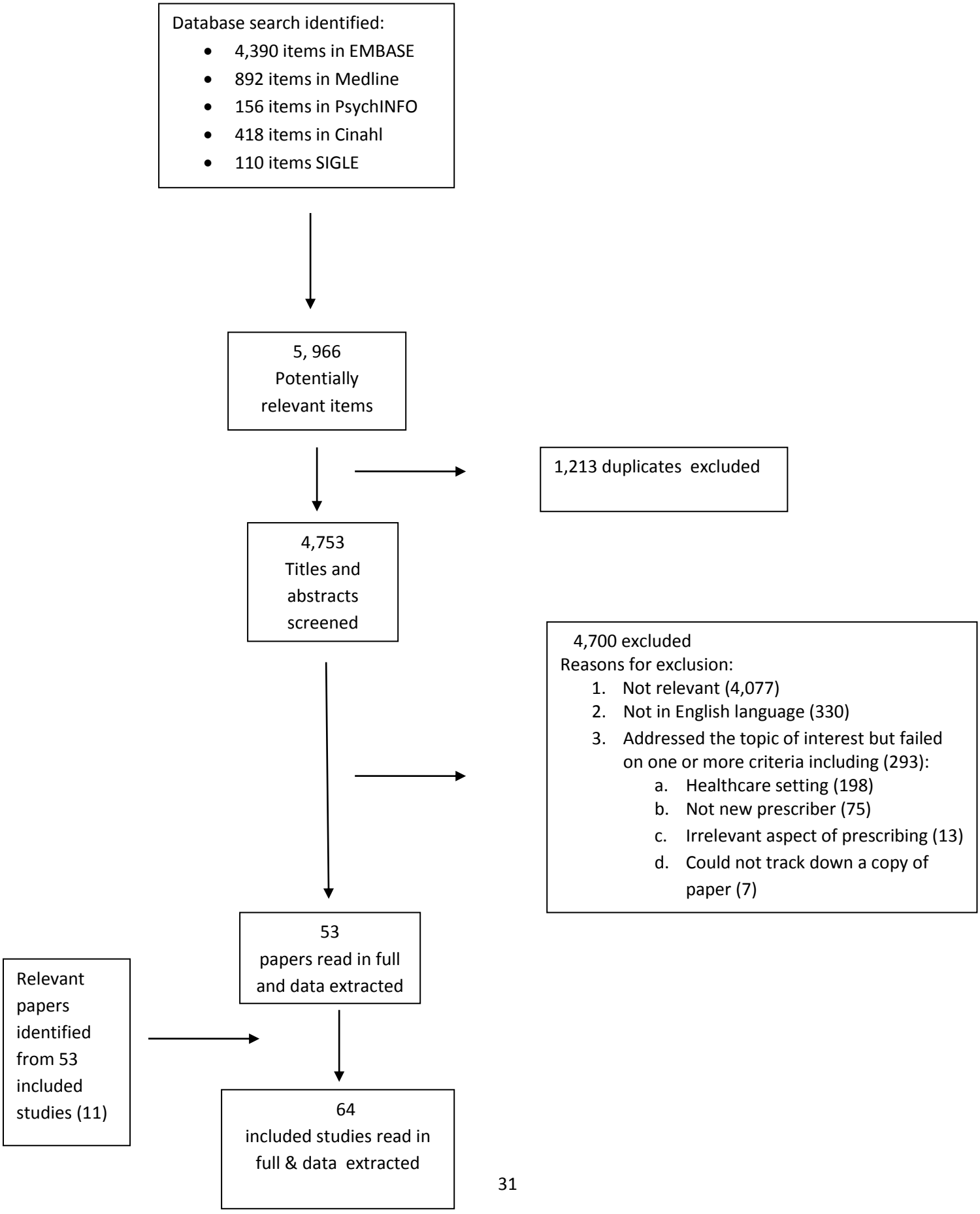
Table 6: Scores of Included Studies on applicable MERSQI Domains

MERSQI Domains	Total Achievable Score	Mean Score	% Mean Score	Standard Deviation
Study Design	3	1.7	57%	0.5
Sampling	1.5	0.7	47%	0.4
Type of Data	3	3.0	100%	0.2
Data analysis	3	2.8	93%	0.4
Outcomes	3	2.0	66%	0.2
Total Score	13.5*	9.8	73%	1.7

** Note – MERSQI scores in Table 5* were calculated as the percentage of total achievable points (accounting for "non applicable" responses) and then adjusted to a standard denominator of 18

This is a post-print author's draft of an article accepted for publication in the journal British Journal of Clinical Pharmacology 2013. DOI:10.1111/j.1365-2125.2012.04397.x

Fig 1: Flow Chart of Study Selection



References

1. Department of Health. Building a safer NHS for patients. London: NHS2001.

2. Lewis P, Dornan T, Taylor D, Tully M, Wass V, Ashcroft D. Prevalence, incidence and nature of prescribing errors in hospital inpatients. Drug Safety. 2009;32:379-89.

3. Ross S, Loke YK. Do educational interventions improve prescribing by medical students and junior doctors? A systematic review. British Journal of Clinical Pharmacology. 2009;67(6):662-70.

4. Barber N, Rawlins M, Dean Franklin B. Reducing prescribing error: competence, control, and culture. Quality and Safety in Health Care. 2003 December 1, 2003;12(suppl 1):i29-i32.

5. Dean B, Schachter M, Vincent C, Barber N. Causes of prescribing errors in hospital inpatients: a prospective study. The Lancet. 2002;359(9315):1373-8.

6. Weingart NS, Wilson RM, Gibberd RW, Harrison B. Epidemiology of medical error. BMJ. 2000 March 18, 2000;320(7237):774-7.

7. Phillips D, Barker G. A July Spike in Fatal Medication Errors: A Possible Effect of New Medical Residents. Journal of General Internal Medicine. 2010;25(8):774-9.

8. Bleakley A, Brennan N. Does undergraduate curriculum design make a difference to readiness to practice as a junior doctor? Medical Teacher. 2011;33:459-67.

9. Lempp H, Seabrook M, Cochrane M, Rees J. The transition from medical student to doctor: Perceptions of final year students and preregistration house officers related to expected learning outcomes. International Journal of Clinical Practice. 2005;59:324-9.

10. Wall D, Bolshaw A, Carolan J. From undergraduate to pre-registration house officer year: How prepared are students? Medical Teacher. 2006;28:435-9.

11. Health Do. Hospital pharmacy initiative for promoting prudent use of antibiotics in hospitals. London: Department of Health2003.

12. Council MS. Medical Schools Council Safe Prescribing Working Group. London: Medical Schools Council2007.

13. Kennedy T, Regehr G, Rosenfield J, Roberts SW, Lingard L. Exploring the Gap Between Knowledge and Behavior: A Qualitative Study of Clinician Action Following an Educational Intervention. Academic Medicine. 2004;79(5):386-93.

14. McNulty CAM, Boyle P, Nichols T, Clappison P, Davey P. Don't wear me out—the public's knowledge of and attitudes to antibiotic use. Journal of Antimicrobial Chemotherapy. 2007 April 1, 2007;59(4):727-38.

15. Michie S, van Stralen M, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science. 2011;6(1):42.

16. Michie S, Abraham C, Eccles M, Francis J, Hardeman W, Johnston M. Strengthening evaluation and implementation by specifying components of behaviour change interventions: a study protocol. Implementation Science. 2011;6(1):10.

17. Bero L, Grilli R, Grimshaw J, Oxman AD. Module of The Cochrane Database of Systematic Reviews. Oxford: Update Software; Updated quarterly: The Cochrane Collaboration; Issue 1 1997.

18. Bloom B. Effects of continuing medical education on improving physician clinical care and patient health: a review of systematic reviews. . International Journal of Technology Assessment in Health Care. 2005;21(3):380-5.

19. Davis DA, Thomson MA, Oxman AD, Haynes RB. Changing Physician Performance. JAMA: The Journal of the American Medical Association. 1995 September 6, 1995;274(9):700-5.

20. Gill P, Makela K, Vermeulen K, Freemantle N, Ryan G, Bond C, Thorsen T, Haaijer-Ruskamp FM. Changing doctor prescribing behaviour. Pharmacy World & Science. 1999;21(4):158-67.

21. American Heritage. The American heritage medical dictionary. Houghton-Millton Harcourt; 2007; Available from: http://medical.yourdictionary.com/.

22. Reed DA, Cook DA, Beckman TJ, Levine RB, Kern DE, Wright SM. Association Between Funding and Quality of Published Medical Education Research. JAMA: The Journal of the American Medical Association. 2007 September 5, 2007;298(9):1002-9.

23. Chaturvedi S, Sinha P, Chandra P, Desai G. Improving quality of prescriptions with clinical audit. Indian Journal of Medical Sciences. 2008(of Publication: 01 Nov 2008):62 (11) (pp 461-4), 2008.

24. Corfield LF, Trivedi PM, Wilson D. Preoperative cardiac drug administration in general surgical patients: A completed audit. International Journal of Clinical Practice. 2006(of Publication: Oct 2006):60 (10) (pp 1300-2), 2006.

25. Cote GA, Rice JP, Bulsiewicz W, Norvell JP, Christensen K, Bobb A, Postelnick M, Howden CW. Use of physician education and computer alert to improve targeted use of gastroprotection among NSAID users. American Journal of Gastroenterology. 2008(of Publication: May 2008):103 (5) (pp 1097-103), 2008.

26. Lewis AW, Bolton N, McNulty S. Reducing inappropriate abbreviations and insulin prescribing errors through education. Diabetic Medicine. 2010(of Publication: January 2010):27 (1) (pp 125), 2010.

27. O'Connor AB, Lang VJ, Quill TE. Eliminating analgesic meperidine use with a supported formulary restriction. American Journal of Medicine. 2005(of Publication: Aug 2005):118 (8) (pp 885-9), 2005.

28. St. Pierre J. Delirium: A process improvement approach to changing prescribing practices in a community teaching hospital. Journal of Nursing Care Quality. 2005(of Publication: July/September 2005):20 (3) (pp 244-50), 2005.

29. Belgamwar RB, Bloor RN, Frischer M. Use of hospital prescribing data to monitor the implementation of clinical guidelines. Pharmacy Education. 2005(of Publication: 2005):5 (3-4) (pp 219-21), 2005.

30. Campino A, Lopez-Herrera MC, Lopez-De-Heredia I, Valls ISA. Educational strategy to reduce medication errors in a neonatal intensive care unit. Acta Paediatrica, International Journal of Paediatrics. 2009(of Publication: May 2009):98 (5) (pp 782-5), 2009.

31. De Melo DO, Cassettari VC, Ribeiro E. Educational intervention program to optimize the use of antibiotics: Impact on prescribing habits, consumption of antimicrobial agents and cost savings. Revista de Ciencias Farmaceuticas Basica e Aplicada. 2008(of Publication: 2008):29 (3) (pp 251-6), 2008.

32. Regal RE, Osta AD, Parekh VI. Interventions to curb the overuse of acid-suppressive medications on an inpatient general medicine service. P and T. 2010(of Publication: February 2010):35 (2) (pp 86-90), 2010.

33. Riggio JM, Sorokin R, Moxey ED, Mather P, Gould S, Kane GC. Effectiveness of a clinical-decision-support system in improving compliance with cardiac-care quality measures and supporting resident training. Academic medicine : journal of the Association of American Medical Colleges. 2009(of Publication: Dec 2009):84 (12) (pp 1719-26), 2009.

34. Simpson JH, Lynch R, Grant J, Alroomi L. Reducing medication errors in the neonatal intensive care unit. Arch Dis Child Fetal Neonatal Ed. 2004 Nov;89(6):F480-2.

35. Apisarnthanarak A, Srichomkwun P, Sutepvarnon A, Bailey TC, Fraser VJ. The long-term outcomes of an antibiotic control program with and without education. Clinical Infectious Diseases. 2007;45(9):1245-7.

36. Foulks CJ, Krenek G, Maxwell K. The effect of changing the total parenteral nutrition order form on resident physician ordering behavior. Nutrition in clinical practice : official publication of the

American Society for Parenteral and Enteral Nutrition. 1997(of Publication: Feb 1997):12 (1) (pp 30-4), 1997.

37. Gordon DB, Jones HD, Goshman LM, Foley DK, Bland SE. A quality improvement approach to reducing use of meperidine. Jt Comm J Qual Improv. 2000 Dec;26(12):686-99.

38. Kaye KI, Welch SA, Graudins LV, Graudins A, Rotem T, Davis SR, Day RO. Pethidine in emergency departments: Promoting evidence-based prescribing. Medical Journal of Australia. 2005(of Publication: 01 Aug 2005):183 (3) (pp 29-33), 2005.

39. Kozer E, Scolnik D, Macpherson A, Rauchwerger D, Koren G. The effect of a short tutorial on the incidence of prescribing errors in pediatric emergency care. Canadian Journal of Clinical Pharmacology. 2006(of Publication: Sep 2006):13 (3) (pp e285-e91), 2006.

40. LeClaire AC, Lopez ID, Smith KM, Lewis DA, Rapp RP, Martin CA. Influence of a urinary tract infection empiric treatment pathway on physician prescribing in an academic medical center. Formulary. 2006(of Publication: Feb 2006):41 (2) (pp 74-81), 2006.

41. Metlay JP, Camargo Jr CA, MacKenzie T, McCulloch C, Maselli J, Levin SK, Kersey A, Gonzales R. Cluster-Randomized Trial to Improve Antibiotic Use for Adults With Acute Respiratory Infections Treated in Emergency Departments. Annals of Emergency Medicine. 2007(of Publication: Sep 2007):50 (3) (pp 221-30), 2007.

42. Grindrod KA, Patel P, Martin JE. What interventions should pharmacists employ to impact health practitioners' prescribing practices? Annals of Pharmacotherapy. 2006(of Publication: Sep 2006):40 (9) (pp 1546-57), 2006.

43. Oxman AD, Thomson MA, Davis DA, Haynes RB. No magic bullets: a systematic review of 102 trials of interventions to improve professional practice. Canadian Medical Association Journal. 1995 November 15, 1995;153(10):1423-31.

44. O' Brien M, Oxman AD, Davis DA, Haynes RB, Freemantle N, Harvey E. Educational outreach visits: effects on professional practice and healthcare outcomes: The Cochrane Collaboration2007.

45. Pawson R, Greenhalgh T, Harvey G, Walshe K. Realist review - a new method of systematic review designed for complex policy interventions. Journal of Health Services Research and Policy. 2005;10(1):21-34.

46. Begg CB, Berlin JA. Publication Bias: A Problem in Interpreting Medical Data. Journal of the Royal Statistical Society Series A (Statistics in Society). 1988;151(3):419-63.

47. Craig P, Dieppe P, Macintyre S, Nazareth I, Petticrew M. Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ. 2008;337(1655):979-83.

48. Akter SFU, Heller RD, Smith AJ, Milly AF. Impact of a training intervention on use of antimicrobials in teaching hospitals. Journal of Infection in Developing Countries. 2009(of Publication: 2009):3 (6) (pp 447-51), 2009.

49. Allenet B, Bedouch P, Brudieu E, Chen C, Chevrot D, Tessier A, Trivin C, Rousseau A, Colle E, Calop J. Physicians' acceptance of pharmacy residents' recommendations on drug therapy. Pharmacy Education. 2004(of Publication: Jun 2004):4 (2) (pp 63-7), 2004.

50. Angalakuditi M, Sunderland VB, Roberts MJ, Turner S, Lilley BJ. Impact of an educational program on antibiotic use in paediatric appendectomy procedures. Journal of Pharmacy Practice and Research. 2005(of Publication: Mar 2005):35 (1) (pp 21-4), 2005.

51. Apisarnthanarak A, Danchaivijitr S, Khawcharoenporn T, Limsrivilai J, Warachan B, Bailey TC, Fraser VJ. Effectiveness of education and an antibiotic-control program in a tertiary care hospital in Thailand. Clinical Infectious Diseases. 2006(of Publication: 15 Mar 2006):42 (6) (pp 768-75), 2006.

52. Apisarnthanarak A, Yatrasert A, Mundy LM, Thammasat University Antimicrobial Stewardship T. Impact of education and an antifungal stewardship program for candidiasis at a Thai tertiary care center. Infection Control & Hospital Epidemiology. 2010;31(7):722-7.

53. Bantar C, Sartori B, Vesco E, Heft C, Saul M, Salamone F, Oliva ME. A hospitalwide intervention program to optimize the quality of antibiotic use: impact on prescribing practice, antibiotic consumption, cost savings, and bacterial resistance. Clin Infect Dis. 2003 Jul 15;37(2):180-6.

54. Bell N. Antibiotic resistance: the Iowa experience. American Journal of Managed Care. 2002;8(11):988-94.

55. Bergqvist M, Ulfvarson J, Karlsson EA. Nurse-led medication reviews and the quality of drug treatment of elderly hospitalized patients. European Journal of Clinical Pharmacology. 2009;65(11):1089-96.

56. Buckmaster ND, Heazlewood V, Scott IA, Jones M, Haerer W, Hillier K. Using a clinical pathway and education to reduce inappropriate prescribing of enoxaparin in patients with acute

coronary syndromes: A controlled study. Internal Medicine Journal. 2006(of Publication: Jan 2006):36 (1) (pp 12-8), 2006.

57. Burmester MK, Dionne R, Thiagarajan RR, Laussen PC. Interventions to reduce medication prescribing errors in a paediatric cardiac intensive care unit. Intensive Care Medicine. 2008(of Publication: June 2008):34 (6) (pp 1083-90), 2008.

58. Buyle F, Vogelaers D, Peleman R, Van Maele G, Robays H. Implementation of guidelines for sequential therapy with fluoroquinolones in a Belgian hospital. Pharmacy World and Science. 2010(of Publication: June 2010):32 (3) (pp 404-10), 2010.

59. Carson RWR, Jacob P, McQuillan R. Towards safer use of opioids. Irish Medical Journal. 2009(of Publication: 2009):102 (8) , 2009.

60. Caswell L, Hoosen I, Vassilas CA, Haque S. Reducing hypnotic use on two older adult functional wards: An effective audit? Psychiatric Bulletin. 2006(of Publication: Mar 2006):30 (3) (pp 95-7), 2006.

61. Cohn SL, Adekile A, Mahabir V. Improved use of thromboprophylaxis for deep vein thrombosis following an educational intervention. J Hosp Med. 2006 Nov;1(6):331-8.

62. De Miguel V, Vargas E, Portoles A, Puerro M, Terleira AI, Moreno A. Modification of albumin use pattern after an educational intervention. Disease Management and Health Outcomes. 2000(of Publication: 2000):8 (1) (pp 43-50), 2000.

63. Donovan JL, Schroeder WS, Tran MT, Foster K, Forrest A, Lee TB, Gandhi PJ. Assessment of eptifibatide dosing in renal impairment before and after in-service education provided by

pharmacists. Journal of Managed Care Pharmacy. 2007(of Publication: Sep 2007):13 (7) (pp 598-606), 2007.

64. Frush K, Hohenhaus S, Luo X, Gerardi M, Wiebe RA. Evaluation of a web-based education program on reducing medication dosing error: A multicenter, randomized controlled trial. Pediatric Emergency Care. 2006(of Publication: Jan 2006):22 (1) (pp 62-70), 2006.

65. Garbutt J, Milligan PE, McNaughton C, Highstein G, Waterman BM, Dunagan WC, Fraser VJ. Reducing medication prescribing errors in a teaching hospital. Joint Commission journal on quality and patient safety / Joint Commission Resources. 2008(of Publication: Sep 2008):34 (9) (pp 528-36), 2008.

66. Gommans J, McIntosh P, Bee S, Allan W. Improving the quality of written prescriptions in a general hospital: The influence of 10 years of serial audits and targeted interventions. Internal Medicine Journal. 2008(of Publication: Apr 2008):38 (4) (pp 243-8), 2008.

67. Gyssens IC, Blok WL, Van Den Broek PJ, Hekster YA, Van Der Meer JWM. Implementation of an educational program and an antibiotic order form to optimize quality of antimicrobial drug use in a department of internal medicine. European Journal of Clinical Microbiology and Infectious Diseases. 1997(of Publication: 1997):16 (2) (pp 904-12), 1997.

68. Khalili H, Dashti-Khavidaki S, Talasaz AHH, Tabeefar H, Hendoiee N. Descriptive analysis of a clinical pharmacy intervention to improve the appropriate use of stress ulcer prophylaxis in a hospital infectious disease ward. Journal of Managed Care Pharmacy. 2010(of Publication: March 2010):16 (2) (pp 114-21), 2010.

69. Leonard MS, Cimino M, Shaha S, McDougal S, Pilliod J, Brodsky L. Risk reduction for adverse drug events through sequential implementation of patient safety initiatives in a children's hospital. Pediatrics. 2006 Oct;118(4):e1124-9.

70. Lipsky BA, Baker CA, McDonald LL, Suzuki NT. Improving the appropriateness of vancomycin use by sequential interventions. American Journal of Infection Control. 1999(of Publication: 1999):27 (2) (pp 84-90), 1999.

71. Lutters M, Harbarth S, Janssens J-P, Freudiger H, Herrmann F, Michel J-P, Vogt N. Effect of a Comprehensive, Multidisciplinary, Educational Program on the Use of Antibiotics in a Geriatric University Hospital. Journal of the American Geriatrics Society. 2004;52(1):112-6.

72. McQuillan R, Finlay I, Branch C, Roberts D, Spencer M. Improving analgesic prescribing in a general teaching hospital. Journal of Pain and Symptom Management. 1996(of Publication: Mar 1996):11 (3) (pp 172-80), 1996.

73. Peeters MJ, Pinto SL. Assessing the impact of an educational program on decreasing prescribing errors at a University hospital. Journal of Hospital Medicine. 2009(of Publication: 2009):4 (2) (pp 97-101), 2009.

74. Perez A, Dennis RJ, Rodr, x00Ed, guez B, Castro AY, Delgado V, Lozano JM, Castro MC. An interrupted time series analysis of parenteral antibiotic use in Colombia. Journal of Clinical Epidemiology. 2003;56(10):1013-20.

75. Record KE, Dickens GR, Amerson AB, Rapp RP. Implementation of a criteria-based antimicrobial formulary system. American Journal of Health-System Pharmacy. 1995((pp S34-S38), 1995):52 (6 SUPPL.

76. Richards MJ, Robertson MB, Dartnell JGA, Duarte MM, Jones NR, Kerr DA, Lim LL, Ritchie PD, Stanton GJ, Taylor SE. Impact of a web-based antimicrobial approval system on broad-spectrum cephalosporin use at a teaching hospital. Medical Journal of Australia. 2003(of Publication: 21 Apr 2003):178 (8) (pp 386-90), 2003.

77. Roberts GW, Adams R. Impact of introducing anticoagulation-related prescribing guidelines in a hospital setting using academic detailing. Therapeutics and Clinical Risk Management. 2006(of Publication: 2006):2 (3) (pp 309-16), 2006.

78. Roth EJ, Plastaras CT, Mullin MS, Fillmore J, Moses ML. A simple institutional educational intervention to decrease use of selected expensive medications. Archives of Physical Medicine & Rehabilitation. 2001;82(5):633-6.

79. Ruttimann S, Keck B, Hartmeier C, Maetzel A, Bucher HC. Long-term antibiotic cost savings from a comprehensive intervention program in a medical department of a university-affiliated teaching hospital. Clin Infect Dis. 2004 Feb 1;38(3):348-56.

80. Sarasin FP, Maschiangelo ML, Schaller MD, Heliot C, Mischler S, Gaspoz JM. Successful implementation of guidelines for encouraging the use of beta blockers in patients after acute myocardial infarction. American Journal of Medicine. 1999(of Publication: May 1999):106 (5) (pp 499-505), 1999.

81. Seto WH, Ching TY, Kou M, Chiang SC, Lauder IJ, Kumana CR. Hospital antibiotic prescribing successfully modified by 'immediate concurrent feedback'. Br J Clin Pharmacol. 1996 Mar;41(3):229-34.

82. Shaw J, Harris P, Keogh G, Graudins L, Perks E, Thomas PS. Error reduction: academic detailing as a method to reduce incorrect prescriptions. European Journal of Clinical Pharmacology. 2003;59(8-9):697-9.

83. Shah AN, Frush K, Luo X, Wears RL. Effect of an intervention standardization system on pediatric dosing and equipment size determination: a crossover trial involving simulated resuscitation events. Arch Pediatr Adolesc Med. 2003 Mar;157(3):229-36.

84. Solomon DH, Van Houten L, Glynn RJ, Baden L, Curtis K, Schrager H, Avorn J. Academic detailing to improve use of broad-spectrum antibiotics at an academic medical center. Archives of Internal Medicine. 2001(of Publication: 2001):161 (15) (pp 1897-902), 2001.

85. Sterne SC, Hayward SL, Ferrill MJ, Iteen SA. Impact of pharmacy efforts to promote the optimal use of ranitidine in a university teaching hospital. Journal of Pharmacy Technology. 1996(of Publication: Sep 1996):12 (5) (pp 207-13), 1996.

86. Thamlikitkul V, Danchaivijitr S, Kongpattanakul S, Ckokloikaew S. Impact of an educational program on antibiotic use in a tertiary care hospital in a developing country. Journal of Clinical Epidemiology. 1998;51(9):773-8.

87. Thompson A, Sullivan SA, Barley M, Strange SO, Moore L, Rogers P, Sipos A, Harrison G. The DEBIT trial: an intervention to reduce antipsychotic polypharmacy prescribing in adult psychiatry wards - a cluster randomized controlled trial. Psychol Med. 2008 May;38(5):705-15.

88. Thompson A, Sullivan S, Barley M, Moore L, Rogers P, Sipos A, Harrison G. Effectiveness of a cognitive behavioural workbook for changing beliefs about antipsychotic polypharmacy: Analysis

from a cluster randomized controlled trial. Journal of Evaluation in Clinical Practice. 2010 Jun;16(3):520-8.

89. Ungvari GS, Chow LY, Chiu HFK, Ng FS, Leung T. Modifying psychotropic drug prescription patterns: A follow-up survey. Psychiatry and Clinical Neurosciences. 1997(of Publication: 1997):51 (5) (pp 309-14), 1997.

90. van Hees BC, de Ruiter E, Wiltink EH, de Jongh BM, Tersmette M. Optimizing use of ciprofloxacin: A prospective intervention study. Journal of Antimicrobial Chemotherapy. 2008(of Publication: Jan 2008):61 (1) (pp 210-3), 2008.

91. Webbe D, Dhillon S, Roberts CM. Improving junior doctor prescribing - The positive impact of a pharmacist intervention. Pharmaceutical Journal. 2007(of Publication: 03 Feb 2007):278 (7437) (pp 136-138), 2007.

92. Zamin MT, Pitre MM, Conly JM. Development of an intravenous-to-oral route conversion program for antimicrobial therapy at a Canadian tertiary care health facility. Ann Pharmacother. 1997 May;31(5):564-70.